TPF Telescope I&T Concepts

Andrew Smith (GSFC)
Raymond Ohl (GSFC)

Challenges

- Primary Mirror is **large!**

How is the mirror mounted & how is it tested?

- Static and dynamic tolerances are very small.

How do we test the instrument for mechanical & thermal stability?

- How do we do a convincing end-to-end test to show that the instrument will measure contrasts of 10^{10} or better at the desired IWA in orbit?

Verification Approach

- Full end-to-end testing simulating realistic targets and environments (thermal, vibrational) may not be possible. Adopt incremental verification. Subsystem models developed and validated through testing. These models are then used with limited testing to verify final performance. During testing adequate margins are maintained to account for model and test uncertainties.

- Some JWST test facilities can be used. Will likely have to build new or modify substantially important facilities such as test stands, vibration isolation systems and a LN2 shroud.

Telescope Static Performance

Surface errors for primary & secondary mirrors derived from specified PSD. $PSD_{TDM} \rightarrow PSD_{TPF}$.

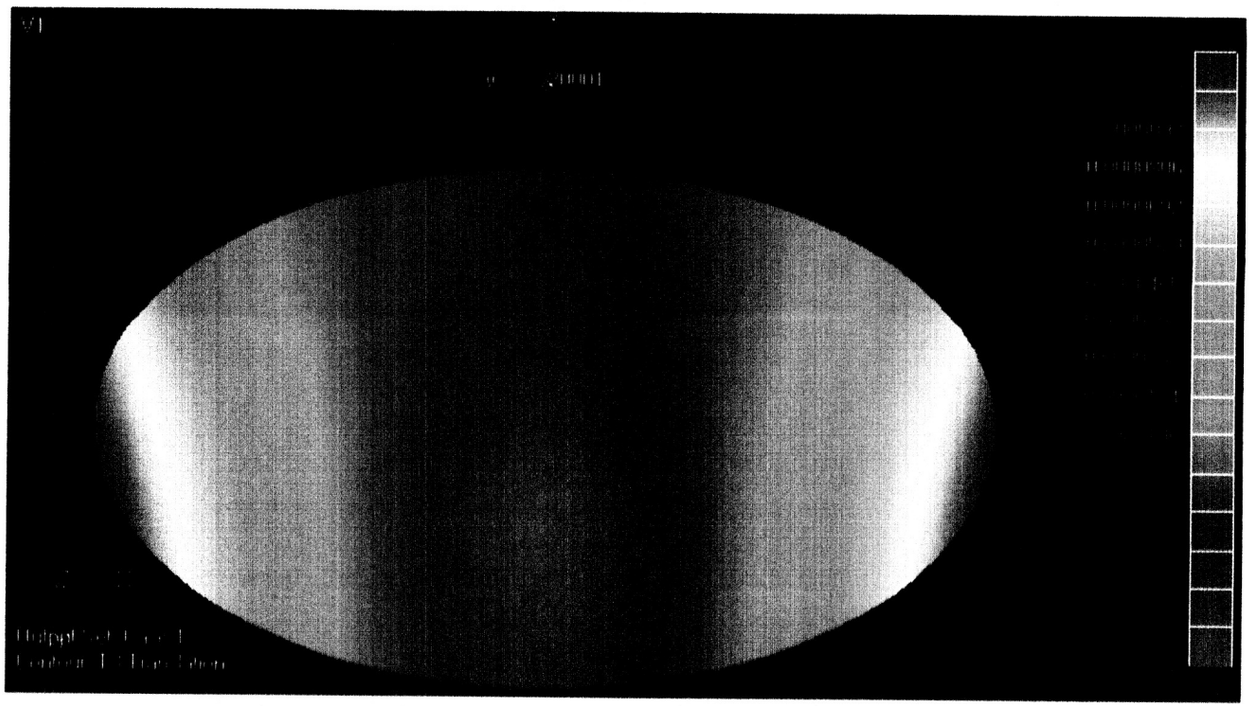
Error budget for the Technology Demonstration Mirror (TDM)

Spatial Frequency	Error in Surface Quality
Low ($\lambda > 40$ cm)	10.00 nm rms
Mid (40cm $> \lambda >$ 2 cm)	4.79 nm rms
High (2 cm $> \lambda >$ 1 mm)	1.44 nm rms

a) WFE measured on earth with gravity off-loading, probably no better than 250 nm rms, mid frequencies

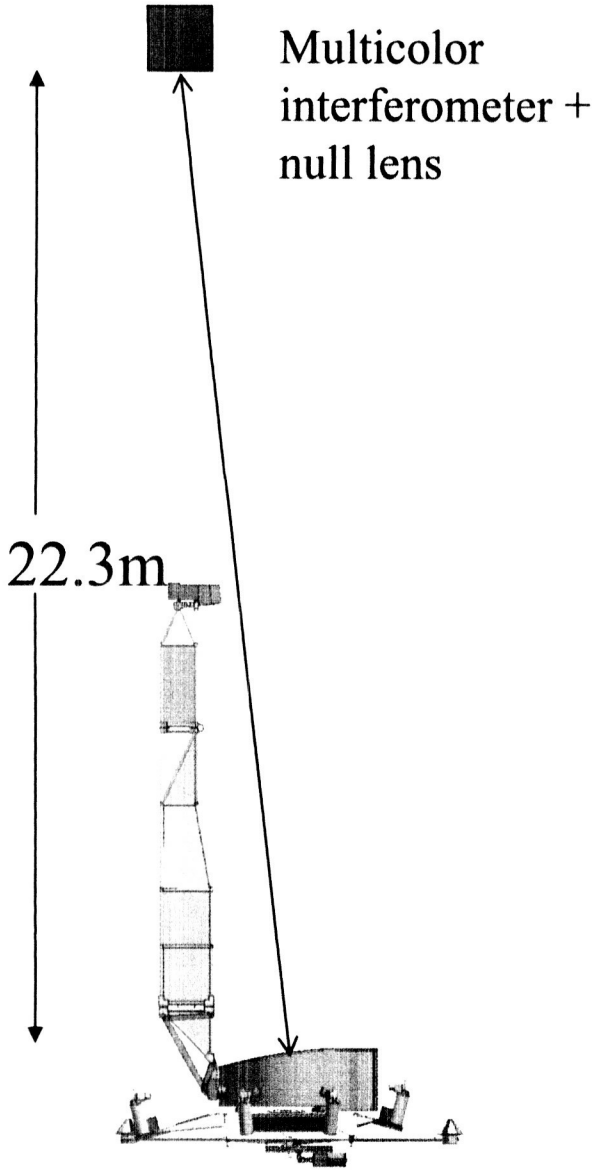
b) WFE modeled performance in 0-g, probably better than 25 nm rms, mid frequencies

Sag of primary mirror under due to gravity with rigid body motions (piston and tilt) subtracted. The gravity vector is directed perpendicular to the viewing plane. Courtesy of Andy Kissil.



The mirror is supported by three bi-pod supports connected to a rigid AMS. The peak-to-peak deformation is 180 microns and must be largely removed to permit telescope alignment and present a wavefront quality that can be accommodated by the coronagraph.

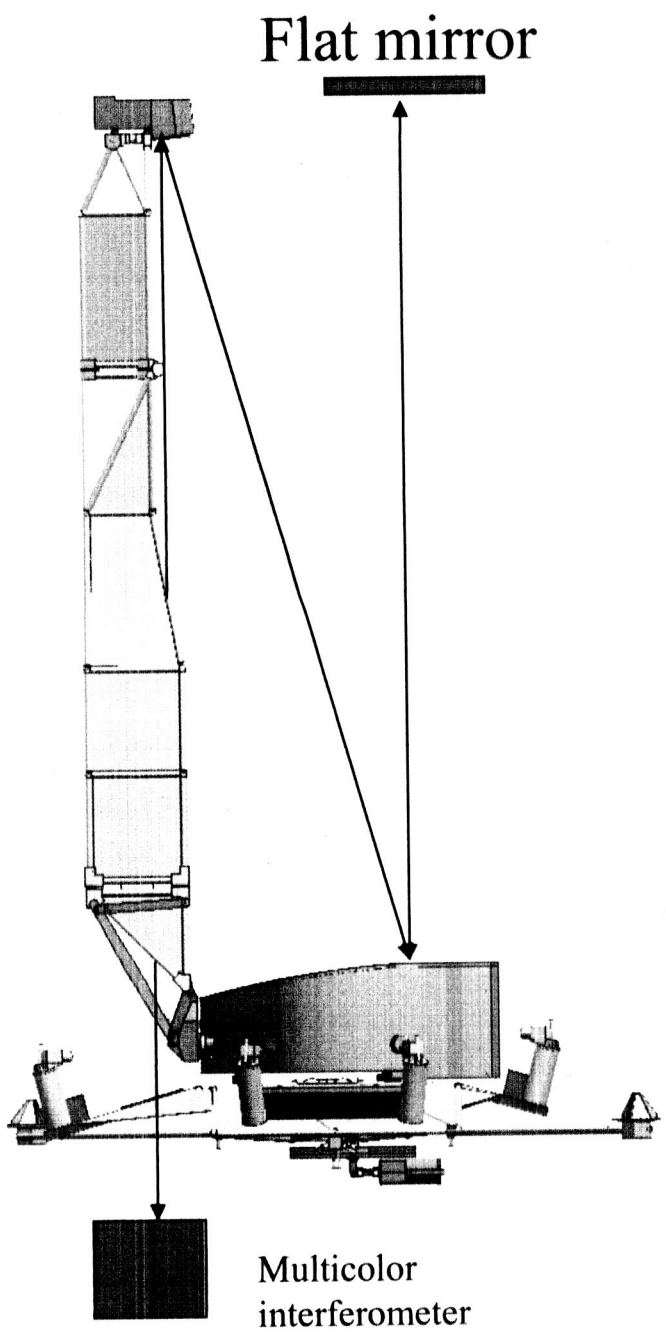
OTA WFE Static Tests:
1. Center of Curvature Test



In principle, a comparison of light reflected back through the null lens with a reference beam will measure the departure of the actual mirror surface from the ideal surface.

- Position and angle adjustments of the PM will permit location of the center-of curvature in the required position relative to the AMS.
- Actuators off-load gravity and test will permit the PM surface error to be minimized.

View AMS as primary reference surface.

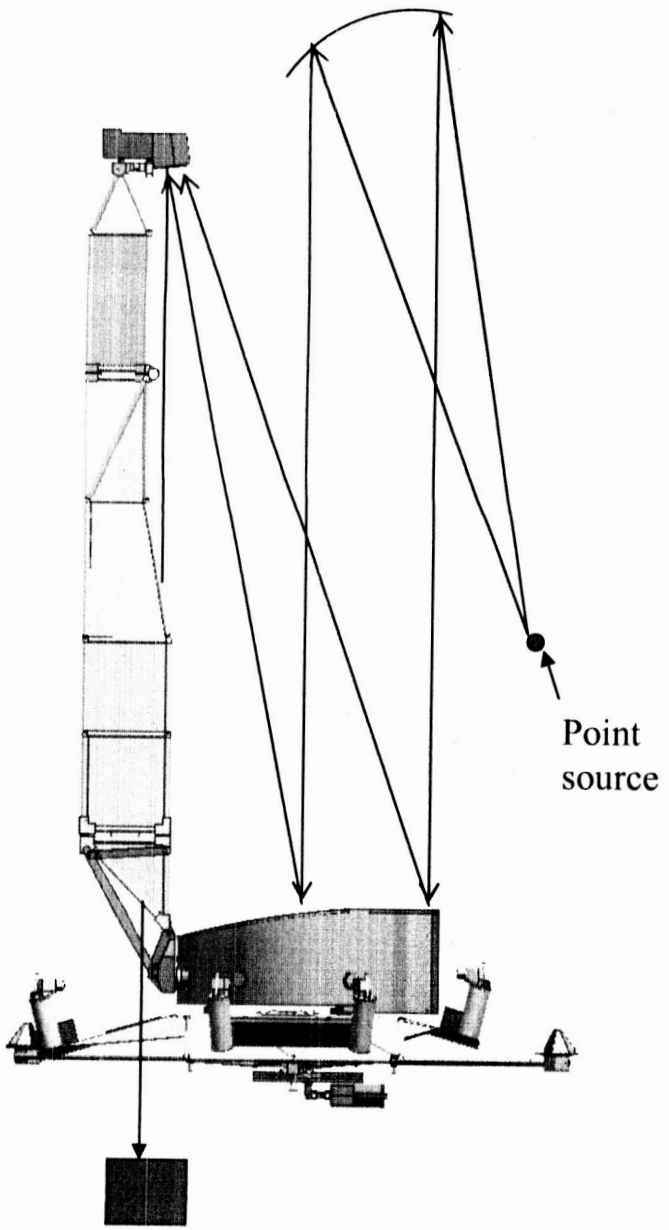


OTA WFE Static Tests:
2. Telescope test (double pass)

Autocollimate off flat to adjust secondary mirror. Can not test wavefront from whole mirror, but must "stitch" together measurements from contiguous parts of the mirror. We will inherit this technique from JWST work.

In this configuration the flat(s) would be made to be flat when facing downward.

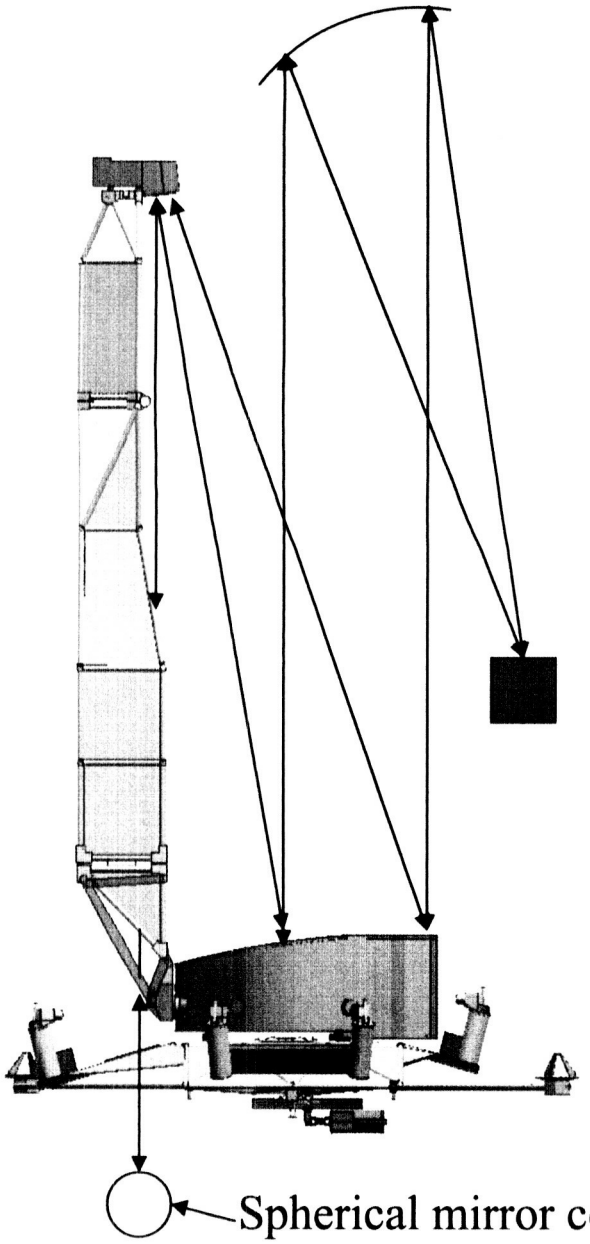
Off-axis collimator



OTA WFE Static Tests:
2. Telescope test (single pass)

- It may be easier to make an off-axis collimator than a flat mirror. Single pass illumination needs a direct measurement of the wavefront with, for example, a phase retrieval system.
- Again only part of the primary can be sampled.
- It will be difficult to fabricate a target simulating a planet and its parent star with the focal length of an off-axis collimator.
- If the collimator is used for a telescope test only then an on-axis system would suffice.

Off-axis collimator



Spherical mirror centered on Cassegrain focus

Alternative secondary mirror alignment scheme

Multicolor interferometer

End-to-End Tests

Partial Illumination of the TPF Aperture

Assume that telescope and coronagraph have been tested and performance verified separately. I&T consists of aligning the telescope and coronagraph and observing 10^{10} contrast at an IWA consistent with the diameter of the aperture illumination. If the observed contrast agrees with the contrast predicted by our high fidelity integrated model then we have shown that the instrument will perform as planed in orbit. Will require special masks

Full Aperture Tests

- If 10^{10} contrast is not possible with full aperture illumination, contrast testing to some level is and it should agree with an integrated model. Full aperture testing will augment subaperture tests.

- Check on impact of low spatial frequencies. Are low frequencies correctable by DM(s)?

- Provide useful alignment check of flight occulter and Lyot masks.

- Provide a PSF narrow enough for relevant system stability measurements, i.e thermal and vibrational stability tests.

Full Aperture Illumination System Design

- 6 m diameter off-axis parabola similar to GSE mirror currently being fabricated by U of AZ Mirror Lab
- Microroughnes: ~1nm rms

  Mid-frequencies: TBD

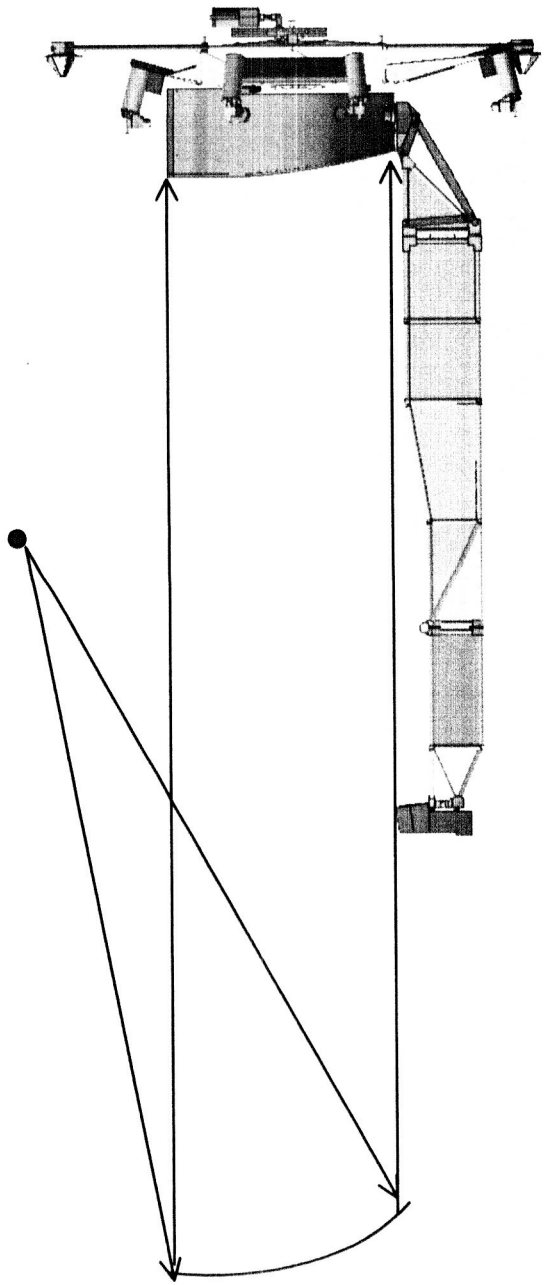
  Figure: ~20 nm rms
- Figure is corrected to orders of magnitude better than the TPF-C primary mirror with:

  a) small fiducialized mirror (Tinsley)

  b) holographic optical element (Andersen/Lyon)

  c) DM

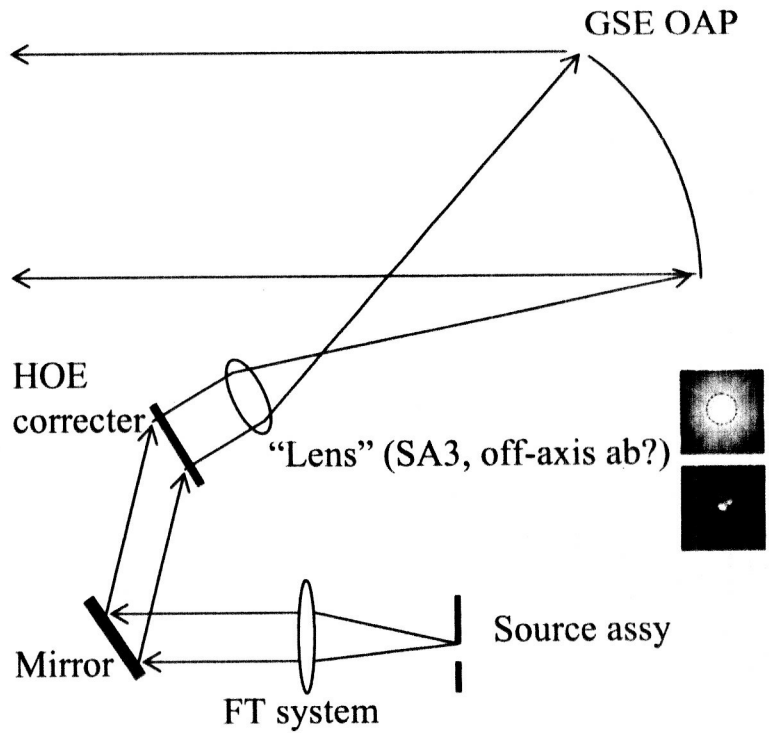
g



Source assembly
-Light source(s)
-Pinhole mask
-Baffles
-Corrector optics
(figure+mid-freq)

Wavefront correction schemes

- Matched corrector mirror (e.g., R. Lyon, Tinsley, et al.)
- DM+wavefront sensor (e.g., in situ radius of curvature interferometry)
- Holographic optical element (HOE; e.g., G. Andersen et al., R. Lyon et al.) + SA3; Cartoon:



Aperture Illumination by Sparse, Phased array of Collimators

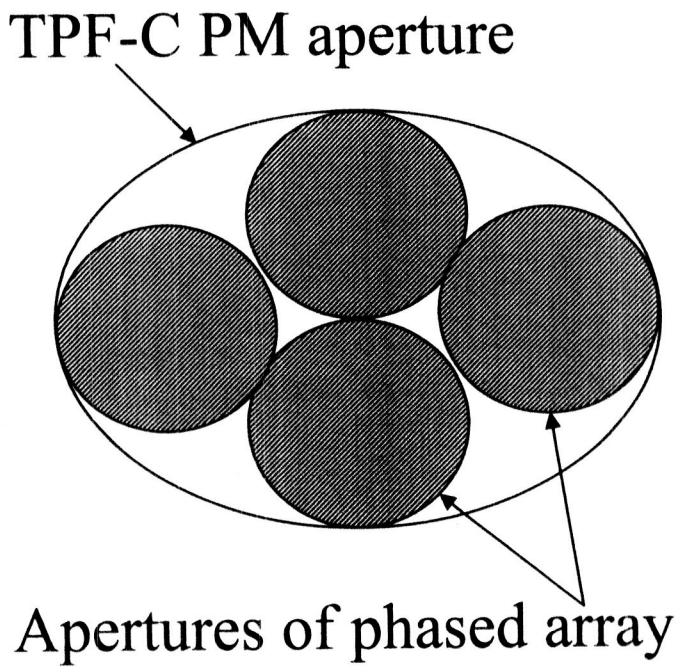
- Narrow FWHM of PSF at occulter, but with significant side lobes. Might find useful side lobe pattern, which could be used with integrated model to validate instrument performance.

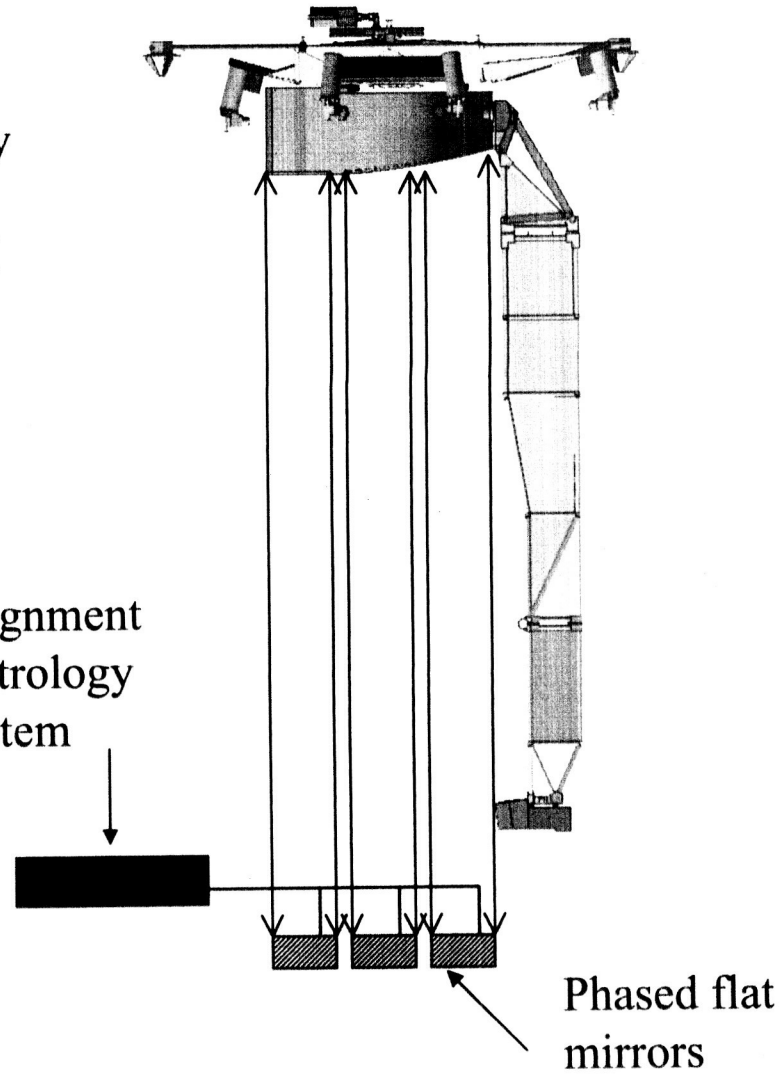
- Aid to alignment with occulter, enables stability measurements.

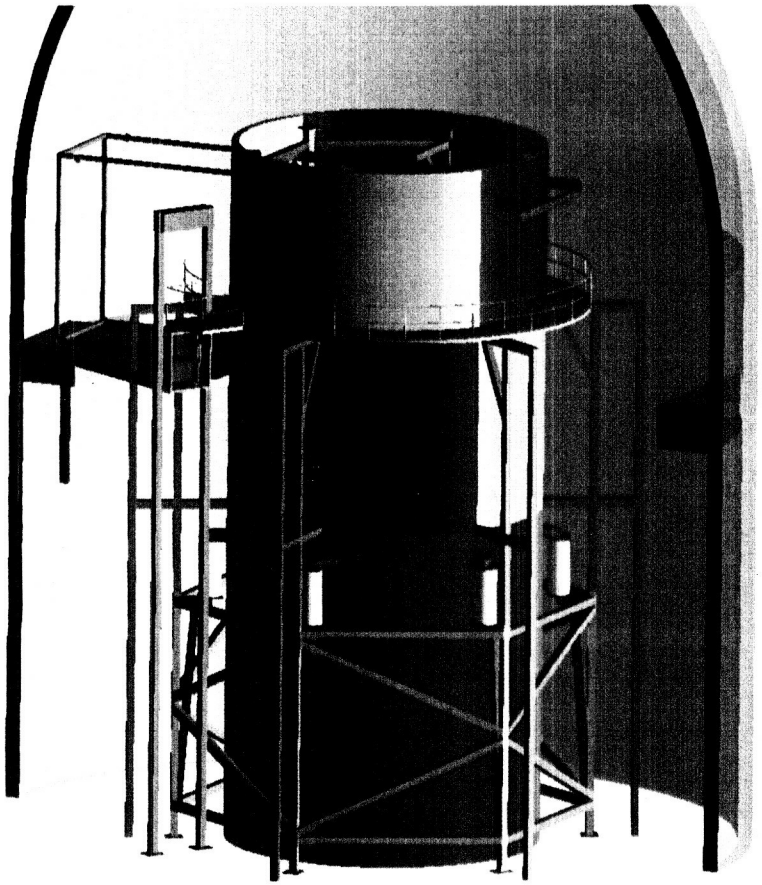
- Cost may be lower than large collimator with correction system, but worse "sanity check" for low frequencies.

Design of phased collimator array

- Example 1: 4 high-quality, parabolic (obscured) mirrors fed with same source & metrology system
- Example 2: 4 high-quality, flat mirrors & metrology system (e.g., interferometer) for TPF-C tested in double-pass using a source assembly behind the PM (similar to JWST scheme, but phased)







The present LN2 shroud will have to be modified or replaced to accommodate the minimum mission sunshield design.

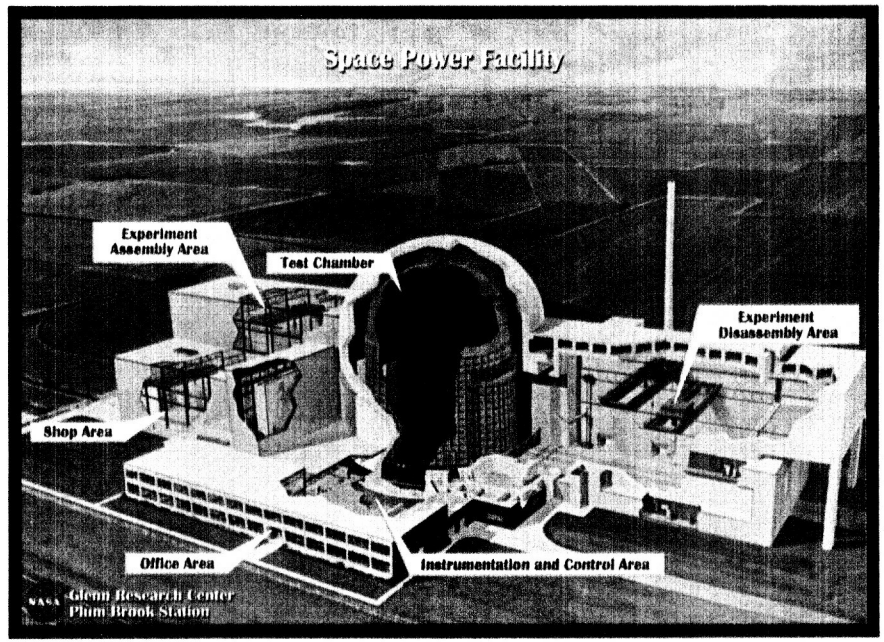
Plum Brook Facility

30 m Diam x 37 m High

LN2 shroud diam = 12.2 m

height ~ 30 m

Max sunshield Diam ~14.7m



Current Work

- Thermal Test Plan

Thermal testing of telescope/coronagraph with sunshield in place is not possible with present facilities. The test will require a larger LN2 shroud and equally cold surface in front of the Sunshield opening. Simulated solar illumination of the Sunshield is being studied.

- Vibration Environment Mitigation

We are studying ways to adequately isolate the TPF from ambient vibrations. The goal is to make background noise negligible & introduce vibrations simulating wheel noise.

- Ancillary Optics

We are exploring the possibilities of fabricating and qualifying large test optics such as flats and off-axis collimators.

Current work (continued)

- End-to-End Tests

We are working on ways to perform end-to-end tests involving partial & full illumination of the primary mirror.

- We are beginning to explore the metrology problems and techniques.